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(54) **Power supply to a stator of a polyphase reluctance machine**

Energieversorgung für den Stator einer mehrphasigen Reluktanzmaschine

Dispositif pour alimenter en énergie le stator d'une machine à reluctance polyphase

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- **PATENT ABSTRACTS OF JAPAN vol. 017, no. 668 (E-1473) 09 December 1993 & JP 05 219 787 A (BROTHER IND LTD) 27 August 1993**

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Description

[0001] This invention relates to polyphase reluctance machines.

[0002] A polyphase switched reluctance machine, running either as a motor or a generator, normally has two electrical connections for each phase between the switching circuitry and each phase winding. Other connection schemes have been proposed, where two or more phases have one connection in common. In these cases the number of electrical connections will be fewer than twice the number of phases but never as few as the number of phases itself. Examples of prior art which illustrate the number of connections required by a switched reluctance machine are illustrated in Figures 1 to 3.

[0003] Figure 1 shows a typical converter circuit in which a three-phase switched reluctance motor is chosen for the purposes of illustration. Six electrical connections are required to the motor, shown at the ends of the motor phase windings 11,12 and 13. Energy is injected into a winding when both switches at the ends of each winding conduct together. Energy is returned from the winding to the dc supply 1 and its dc link capacitor 2 when the two diodes associated with each pair of switches conduct. If one switch and one diode of a phase conduct together, no energy flows to or from the dc supply - this is known as 'freewheeling'.

[0004] It is desirable to reduce the number of cables required between the machine and its converter circuit since these may be widely separated and the cost of the cables may become a substantial part of the cost of the complete drive. In some applications, the stator may be in a different environment from the cables and there will then be a cost associated with the sealing of each cable entry to the environment.

[0005] Figure 2 shows a converter circuit which may be used on a switched reluctance motor having an even number of phases. This circuit requires n+1 electrical terminals for n phases. A given phase receives energy from one of the capacitors 2,3 and from the dc supply when its switch conducts, and returns energy to the other capacitor and to the dc supply when its diode conducts.

[0006] Figure 3 shows a converter circuit for a three-phase switched reluctance machine having four electrical terminals, one of which is common to all three phases. When a switch (e.g. in the form of a transistor) conducts, its phase receives energy from the dc supply 1 and its capacitor 2 but when its diode conducts the phase returns energy to the capacitor 3 and the resistor 4. Alternatively, the energy returned to the capacitor 3, instead of being dissipated in the resistor 4, may be transferred by an additional switching circuit to the dc supply 1 and its capacitor 2.

[0007] JP-A-5-219787 discloses a drive circuit for a three-phase variable reluctance motor in which the phase windings are connected as phase units in a delta arrangement with a serially connected diode in each phase unit. The motor is supplied using a switch arrangement and one supply line per phase.

[0008] It is an object of the invention to provide an electrical supply to four or more phases of a switched reluctance machine with reduced components.

[0009] According to the invention there is provided a stator for a p-phase (p>3) reluctance machine comprising a stator body, a phase winding for each phase of the machine, and at least one uni-directional current device connected in series with each phase winding to form a phase unit therewith, the p phase, units defining nodes of connections between the phase units, characterised in that the phase units are arranged into a plurality of separate conducting rings.

[0010] Each phase winding of a switched reluctance machine according to the invention has a uni-directional current device connected in series with it to form the phase unit. Two or more phase units are connected in series to form a closed ring in which the conducting directions of the uni-directional current devices allow a current to circulate around the ring. Electrical supply connections to the machine are made at each of the nodes where one phase unit is connected to its neighbour, thus requiring the same number of supply cables as there are phase units in a ring.

[0011] Preferably, the uni-directional current device is a diode. The device may be arranged on one side of its respective phase winding and a further device may be connected to conduct in the same direction on the other side of the same phase winding.

[0012] Preferably, pairs of commonly connected uni-directional current devices at one of the nodes are formed in a single device package.

[0013] In a particular form, a converter circuit for the machine includes switching circuits having a positive and a negative dc supply terminal, serially connected first and second switch means for each phase of the machine and means for transmitting electrical energy between each node of the conducting ring and the first and second switch means of the switching circuit, the pairs of serially connected switch means being connected across the positive and negative supply terminals.

[0014] The means for transmitting electrical energy preferably comprises an electrically conductive line connected from between each of the first and second switch means, and supplying electrical energy to a respective one of the nodes.

[0015] Preferably, each of the first switch means connected with the positive supply terminal includes a diode connected across the said first switch means to conduct towards the positive supply terminal, and each of the second switch means connected with the negative supply terminal includes a diode connected across the said second switch means to conduct from the negative supply terminal.

[0016] Preferably, the converter circuit for the machine includes a snubber capacitor connected across each of the switch means.

[0017] Apart from requiring only n connections for n phases of a ring the invention has the further benefit in that, in contrast to a conventional switched reluctance drive, where the cables of a phase carry a pulsating unidirectional current, the cables for a switched reluctance drive according to the invention carry equal alternating currents. This has a benefit compared with the circuits in Fig.2 or 3 in that the sum of the root mean squared (RMS) currents in the cables is less.

[0018] Significantly, a transformer can be interposed between the converter circuit and the nodes, i.e. in the cable connections carrying the power to the motor. Where these cables are unusually long, e.g.for a submersible pump operating in a very deep well, it is advantageous to design the motor for higher voltages than are convenient for the power converter so that the motor and its cables carry lower current at higher voltages than those occurring within the converter circuit, the step-up in voltage being performed by the transformer interposed between the converter and the cables supplying the motor.

[0019] Also according to the invention there is provided a method of driving a switched reluctance machine as defined above, the method comprising:

a) applying a supply voltage across the positive and negative supply terminals;
b) initiating a phase conduction cycle by turning on the first switch connected with one of the nodes and a second switch connected with another of the nodes, such that a positive voltage is applied to, and flux increases within, the phase winding between the node;
c) turning off the said first and second switch means when the flux in the phase winding between the nodes reaches a required level;
d) initiating a subsequent phase conduction cycle by turning on the first switch means connected with the said other node and the second switch means connected with a further one of the nodes adjacent the said other node; and
e) sequentially turning on and off the first and second switch means connected with the nodes across successive adjacent phase windings according to steps b) to d) to initiate a sequence of phase conduction cycles.

[0020] Preferably, the method includes freewheeling the machine by oscillating the first or second switch means between on and off states repeatedly during the respective phase conduction cycle to reduce the average voltage applied to the phase windings.

[0021] The supply voltage may be varied as a function of the speed of the motor.

[0022] The present invention can be put into practice in various ways, some of which will now be described by way of example with reference to the accompanying drawings in which:

Fig.1 is a circuit diagram of a typical three-phase switch arrangement for an switched reluctance machine according to prior art;
Fig.2 is a circuit diagram of a two-phase switch arrangement using three connections according to prior art;
Fig.3 is a circuit diagram of a three-phase switch arrangement using four connections according to prior art;
Fig.4 is a circuit diagram for a three-phase machine using three connections according to the prior art;
Fig.5 is a circuit diagram of a converter circuit suitable for supplying a switched reluctance machine and showing snubbing capacitors; and
Fig.6 is a diagram of an alternative machine winding arrangement for use in the circuit of Fig.4.

[0023] Referring to Fig.4 of the drawings, an inverter 8 is coupled to a three-phase switched reluctance machine 7 by only three electrical supply lines 10, 12 and 14. For the sake of convenience reference is made to a 'motor'.

[0024] It will be understood by the skilled person that this invention applies equally to reluctance generators. As such the description below is intended to apply mutatis mutandis to reluctance generators.

[0025] In more detail, pairs of serially connected semi-conductor switches S_1/S_6; S_3/S_2; S_5/S_4 are connected in parallel between positive and negative terminals of a supply voltage source V_s. A dc link capacitor 16 is also connected across the positive and negative supply terminals. Each of the positive-side switches S_1; S_3; S_5 has a recirculating diode D_1; D_3; D_5 connected across it to conduct towards the positive supply terminal. Each of the negative-side switches S_6; S_2; S_4 has a recirculating diode D_6; D_2; D_4 connected across it to conduct from the negative supply terminal. Single diodes D_1-D_6 are shown. However, it will be appreciated by the skilled person that two or more diodes could be used, in place of each single diode shown, connected in parallel or in series.

[0026] The three-phase motor 7 comprises three phase units, each comprising a phase winding RS; ST; TR and a serially connected phase diode DR; DS; DT. Depending on current requirements the phase diode may, in fact, each be a set of diodes connected in parallel. The phase units are connected in a delta configuration with each phase diode connected to conduct toward its winding. Each phase diode may be connected on the other side of its winding to equal effect. The diodes in the delta arrangement are thus arranged to allow current to circulate around the delta. The connections between the phase units define nodes R;S;T. The lines 10, 12 and 14 are each respectively connected between one of each of the nodes and the junction between the switches of one of the pairs of switches of the invertor. Thus, for a three-phase switched reluctance motor winding only the three lines 10, 12 and 14 are needed to supply the winding current.

[0027] It will be appreciated that a motor with a plurality of phases can be split into groups (say a six-phase machine sub-divided into two delta groups, each delta having three phases). Each delta group may be fed by its own inverter such that there is still only one line per phase of the machine. Actuation of each of the separate inverters can be adjusted relative to the other. This then allows the control of the machine to reduce vibration, acoustic noise and output torque ripple because of the ability to shift the actuation of one set of phases relative to the other.

[0028] Hitherto, it has been thought that a standard 3-phase inverter cannot be used for driving switched reluctance machines because it provides alternating currents to the machine, whereas a switched reluctance machine is normally operated with uni-directional current in its windings. With the invention, however, it is possible to use the standard 3-phase inverter circuit to advantage.

[0029] The phase units of the machine in this embodiment comprise the winding/diode pairs RS/DR, ST/DS and TR/DT. The connections made to the nodes R, S and T are by cables to the output terminals R', S' and T' of the inverter 8. Alternatively, the inverter terminals R', S' and T' may be connected to the primary of a transformer 18 whose secondary is connected to the cables 10, 12, 14 supplying the motor through the nodes R, S and T.

[0030] There are many ways whereby the windings of the machine may be sequentially energised in synchronism with rotor rotation by control of the active semi-conductor switches S_1-S_6. Any type of semi-conductor or other switch capable of being turned on and off may be used in the circuit. The diodes D_1-D_6 provide for the continuation of current in a connecting cable or transformer winding when a semi-conductor switch of the associated phase is turned off.

[0031] When one upper and one lower semi-conductor switch (as depicted in Fig.4) connected to different nodes of the delta ring of phase units are turned on together, e.g. S_1 and S_2, the phase RS is connected across the dc supply V_s and flux will increase approximately linearly in the magnetic circuit associated with that phase winding. If S_1 and S_2 are both turned off, the current in the phase RS will transfer to D_6 and D_3. The polarity of the voltage across the phase RS reverses and the flux associated with the phase RS decreases approximately linearly. It should be noted that while diodes D_6 and D_3 conduct, a positive potential appears at node S of the motor and a negative potential appears at node R. Thus, the diodes DS and DT are forward biassed and current can increase in phases ST and TR, whilst diodes D_3 and D_6 remain conductive until current in the diodes DS and DT reaches equality with the currents in the diodes D_3 and D_6. Thereafter, the currents in RS, ST and TR, being equal, circulate around the delta connected phase units, eventually decaying to zero.

[0032] A simple method of controlling the switches S_1-S_6 will now be described whereby each winding RS, ST and TR receives in turn a positive voltage V_s followed by a negative voltage $-V_s$ followed by a period of zero current.

[0033] As an initial condition (corresponding to operation at a motor speed typical of normal operation); the windings TR and RS are assumed to carry equal currents, with the current I_{RS} increasing and the current I_{TR} decreasing. The conduction of S_1 and S_2 causes I_{RS} to increase, increasing the flux associated with the phase RS approximately linearly. The conduction of D_4 and S_1, demanded by the current in TR, applies a reverse voltage $-V_s$ to TR, decreasing the flux therein approximately linearly.

[0034] When the flux associated with the phase winding RS reaches the value needed for the motor to exert the required torque, the average value of which for all three phases meets the requirements of the load, S_1 and S_2 are turned off, their current transferring to D_6 and D_3, respectively. Then, or later, S_4 is turned on. In either case a positive voltage V_s is applied to the phase winding ST. S_3 could be turned on with S_4, or later, but it will carry no current until I_{ST} exceeds I_{RS}. Because there is neglible voltage across the switches when they are turned on, the turn-on losses are neglible. S_3 should be turned on before I_{ST} has increased to equality with the decreasing I_{RS}, to avoid turn-on losses, and S_5 should be turned-on before I_{ST} reaches equality with I_{TR}.

[0035] Table 1 summarises the conduction of switches S_1-S_6 and diodes D_1-D_6 with indications of current inequalities and flux variations. These refer to idealised conditions where the machine phase winding resistance and semi-conductor volt-drop of the switches are ignored.

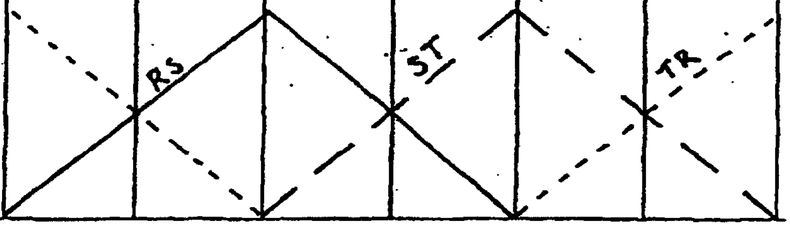
COLUMN #	1	2	3	4	5	6
CURRENTS IN	TR>RS	RS>TR	RS>ST	ST>RS	ST>TR	TR>ST
PHASES	CONDUCTING DEVICES					
RS	D_1+S_2	$S\cancel{D}_1+S_2$	D_3+D_6	S_3+D_6		
ST			D_3+S_4	S_3+S_4	D_5+D_2	S_5+D_2
TR	D_1+D_4	S_1+D_4			D_5+S_6	S_5+S_6
FLUXES						

TABLE 1

[0036] Two points should be noted with respect to Table 1:

1) The flux wave forms are correctly related to the conducting devices, but the incidence of current equality and flux equality will not generally coincide;
2) The conduction sequence refers to a particular direction of machine rotation and a different sequence is required for the opposite direction of rotation which will be apparent to the skilled person.

[0037] Since a flux change is proportional to the product of voltage applied to a phase and the time for which the voltage is applied, it is clear that if the motor speed is halved, the times of voltage application for given switching angles double and if the flux change is not to vary, the voltage V_s must be broadly proportional to motor speed. This implies that the dc voltage V_s on Fig.4 must be capable of being sufficiently varied over a wide range.

[0038] The inverter circuit of Fig.5 offers the opportunity greatly to reduce the switch-off losses in the switches S_1-S_6. Like components are indicated by the corresponding numbering in Fig.4. The conducting lines 10, 12 and 14 are connected to their respective nodes as shown in Fig.4 with or without the transformer 18. Since with the conduction sequence of Table 1 the conduction of the diode, e.g. D_2, always precedes the conduction of the switch, e.g. S_2, it is possible to place snubber capacitors across each switch. This is illustrated by way of example by the snubber capacitors C connected in parallel across the switches S_1-S_6. The presence of the capacitor C across each switch ensures that the voltage across it at turn off is virtually zero because the switch current transfers to the snubber capacitor C. Turn-off losses are thus virtually eliminated. The cable current which was flowing through one of the switches, say S_6, firstly transfers to the parallel snubber capacitor C, the voltage across which increases until the opposite diode, D_1, is forward-biased whereupon the cable current transfers to this diode.

[0039] If the method described above for reducing turn-off losses is not required, more complex conduction patterns, which may provide extra facilities in the way the machine phases are energised, may be employed. For example, during the time when the current in one phase is decreasing and the current in a second subsequent phase (in order of rotor rotation) is increasing and is larger than that in the first phase, an opportunity exists for temporarily freewheeling the phase currents. Referring to the columns of Table 1, the above condition is satisfied for columns 2, 4 and 6. If, during one of these intervals the top switch is turned off (i.e. S_1, S_3 or S_5, as appropriate), when it (and its associated switch) have previously both been conducting, the associated diode (i.e. D_6, D_2 or D_4, as appropriate) will conduct. Thus, all the nodes R, S and T of the motor will be at the potential of the negative dc supply and hence the motor phase currents will be circulating in a freewheeling mode. If the top switch is turned off and on repeatedly during these intervals the average voltage applied to the motor phases can be reduced without the need for reducing the voltage V_s. The repeated off/on switching reduces the average positive voltage applied to the phase winding whose current is increasing and also the average negative voltage applied to the phase winding whose current is decreasing.

[0040] A variety of switching patterns will be apparent to one skilled in the art, each having its own advantages for machine control. In all cases, the advantageous use of only one connecting wire per phase according to the invention is realised.

[0041] The invention uses the configuration for the connection of phases in Figure 4 for n phases (n>3) and arranges them as m conducting rings, where m is an integer never greater than n/2 and never less than 2. The m conducting rings may each comprise at least two phase units and may comprise up to n/2 units (n even) or (n+1)/2 units (n odd). Where two or more conducting rings comprise the same number of phase units, their respective nodes may be supplied by the same cable or by separate cables, thus being able to reduce the number of cables to the number of phase units in a conducting ring. When the conducting rings comprise different numbers of phase units, the total number of cables required is still equal to the number of phases.

[0042] Thus, according to the invention the phases of a four-phase motor may be taken in pairs and each pair of phases connected as for a two-phase motor. The invention is equally applicable to machines with more than four phases, for which the phase units may be configured in a polygon with cable connections to the respective nodes, and in a number of rings, such as deltas.

[0043] A further embodiment of the invention is to use two diodes per phase unit, connected as shown in Fig.6. Each phase unit has a diode at each end of the phase winding, with both diodes arranged to conduct in the same direction as the original diode. This can have advantages in allowing the diodes to share the voltage across the phase unit on high voltage systems. Optionally, adjacent diodes can be contained in a single module 20 as shown in Fig.6.

[0044] While the invention has been described in connection with the illustrative embodiments discussed above, those skilled in the art will recognise that many variations may be made without departing from the present invention. For example, machines such as reluctance machines can be constructed as linear motors in which the moving member is often referred to as a rotor. The term 'rotor' herein is intended to embrace such moving members of linear motors. Accordingly, the above description of several embodiments is made by way of example and not for purposes of limitation. The present invention is intended to be limited only by the scope of the following claims.

Claims

1. A stator for a p-phase (p>3) reluctance machine comprising a stator body, a phase winding (RS, ST, TR, ...) for each phase of the machine, and at least one unidirectional current device (DR, DS, DT, ...) connected in series with each phase winding to form a phase unit therewith, the p phase units defining nodes (R, S, T) of connections between the phase units, **characterised in that** the phase units are arranged into a plurality of separate conducting rings.

2. A stator as claimed in claim 1 in which the at least one uni-directional current device is a diode (DR, DS, DT, ...).

3. A stator as claimed in claim 2 in which two or more diodes are connected in series or in parallel.

4. A stator as claimed in claim 1, 2 or 3 in which each uni-directional current device is connected to one side of its respective phase winding and a further unidirectional current device is connected to the other side of its respective phase winding.

5. A stator as claimed in claim 4 in which pairs of commonly connected uni-directional current devices at one of the nodes are formed in a single device package.

6. A stator as claimed in claim 1, 2, 3, 4 or 5 in which m conducting rings comprise up to n/2 units (n even) or (n+1) /2 units (n odd).

7. A stator as claimed in claim 6 in which at least two conducting rings comprise the same number of phase units and the nodes of each are respectively connected together.

8. A stator as claimed in any of claims 1 to 7, further including a switching circuit having positive and negative dc supply terminals, serially connected first and second switch means (S1-6) for each node and means (10, 12, 14) for transmitting electrical energy between each node of the conducting ring and the first and second switch means of the switching circuit, the pairs of serially connected switch means being connected across the positive and negative supply terminals.

9. A stator as claimed in claim 8 in which the means for transmitting electrical energy include an electrically conductive line (10, 12, 14) connected between each of the first and second switch means and the corresponding node such that the switching circuit is connected by one of the said lines to the corresponding node.

10. A stator as claimed in claim 8 or 9 in which each of the first switch means connected with the positive supply terminal includes a diode (D1, D3, D5) connected across the said first switch means to conduct towards the positive supply terminal and each of the second switch means connected with a negative supply terminal includes a diode (D2, D4, D6) connected across the said second switch means to conduct from the negative supply terminal.

11. A stator as claimed in claim 10 in which a snubber capacitor (C) is connected across each of the switch means.

12. A stator as claimed in claim 8, 9, 10 or 11 in which the means for transmitting electrical energy include a transformer (18).

13. A stator as claimed in claim 6, further including a separately actuatable switching circuit for each conducting ring.

14. A stator as claimed in claim 11 in which each of the switching circuits is as claimed in claim 8, 9, 10, 11 or 12.

15. A polyphase reluctance machine comprising a rotor and a stator as claimed in any preceding claim.

16. A method of driving a switched reluctance machine having a stator as claimed in any of claims 8 to 14, the method comprising:

a) applying a supply voltage across the positive and negative supply terminals;
b) initiating a phase conduction cycle by turning on the first switch connected with one of the nodes and a second switch connected with another of the nodes, such that a positive voltage is applied to, and flux increases within the magnetic circuit associated with, the phase winding between the nodes;
c) turning off the said first and second switch means when the flux associated with the phase winding between the nodes reaches a required level;
d) initiating a subsequent phase conduction cycle by turning on the first switch means connected with the said other node and the second switch means connected with a further one of the nodes adjacent the said other node, such that a positive voltage is applied across the adjacent phase winding between those nodes; and
e) sequentially turning on and off the first and second switch means connected with the nodes of successive adjacent phase units according to steps b) to d) to initiate a cyclic sequence of phase conduction cycles.

17. A method as claimed in claim 16, including freewheeling the current in a phase unit by oscillating the first or second switch means between on and off states repeatedly during a respective phase conduction cycle to reduce the average voltage applied to the phase winding in the cycle.

18. A method as claimed in claim 17, including alternating between oscillating the first and second switch means to effect freewheeling.

19. A method as claimed in claim 16, 17 or 18 in which the dc supply voltage is varied as a function of the speed of the motor.

Patentansprüche

1. Stator für eine p-phasige (p>3) Reluktanzmaschine, der einen Statorkörper, eine Phasenwicklung (RS, ST, TR, ...)

für jede Phase der Maschine und mindestens eine Vorrichtung für in einer Richtung fließenden Strom (DR, DS, DT, ...) aufweist, die in Serie mit jeder Phasenwicklung verbunden ist, um eine Phaseneinheit damit auszubilden, wobei die p Phaseneinheiten verbindungsknoten (R, S, T) zwischen den Phaseneinheiten definieren, **dadurch gekennzeichnet, dass** die Phaseneinheiten in einer Mehrzahl von getrennten Leitungsringen angeordnet sind.

2. Stator wie in Anspruch 1 beansprucht, bei dem die mindestens eine Vorrichtung für in einer Richtung fließenden Strom eine Diode (DR, DS, DT, ...) ist.

3. Stator wie in Anspruch 2 beansprucht, bei dem zwei oder mehr Dioden in Serie oder parallel verbunden sind.

4. Stator wie in Anspruch 1, 2 oder 3 beansprucht, bei dem jede Vorrichtung für in einer Richtung fließenden Strom mit einer Seite ihrer jeweiligen Phasenwicklung verbunden ist und eine weitere Vorrichtung für in einer Richtung fließenden Strom mit der anderen Seite ihrer jeweiligen Phasenwicklung verbunden ist.

5. Stator wie in Anspruch 4 beansprucht, bei dem Paare von gemeinsam verbundenen Vorrichtungen für in einer Richtung fließenden Strom an einem der Knoten in einer einzelnen Vorrichtungspackung ausgebildet sind.

6. Stator wie in Anspruch 1, 2, 3, 4 oder 5 beansprucht, bei dem m leitende Ringe bis zu n/2 Einheiten (n gerade) oder (n+1)/2 Einheiten (n ungerade) umfassen.

7. Stator wie in Anspruch 6 beansprucht, bei dem mindestens zwei leitende Ringe die gleiche Zahl von Phaseneinheiten umfassen und die Knoten jedes Rings jeweils miteinander verbunden sind.

8. Stator wie in einem der Ansprüche 1 bis 7 beansprucht, weiterhin mit einer Schaltelektronik, die positive und negative Gleichatrom-Speiseanschlüsse hat, in Serie verbundenen ersten und zweiten Schalteinrichtungen (S1-6) für jeden Knoten und Einrichtungen (10, 12, 14) zum Übertragen von elektrischer Energie zwischen jedem Knoten des Leitungsrings und den ersten und zweiten Schaiteinrichtungen der Schaltelektronik, wobei die Paare von in Serie verbundenen Schalteinrichtungen quer über den positiven und negativen Speiseanschlüssen verbunden sind.

9. Stator wie in Anspruch 8 beansprucht, bei dem die Einrichtungen zum Übertragen von elektrischer Energie eine stromleitende Leitung (10, 12, 14) umfassen, die zwischen jeder der ersten und zweiten Schalteinrichtungen und dem entsprechenden Knoten verbunden ist, so dass die Schaltelektronik durch eine der Leitungen mit dem entsprechenden Knoten verbunden ist.

10. Stator wie in Anspruch 8 oder 9 beansprucht, bei dem jede der ersten Schalteinrichtungen, die mit dem positiven Speiseanschluss verbunden sind, eine Diode (D1, D2, D3) enthält, die quer über der ersten Schalteinrichtung verbunden ist, um in Richtung auf den positiven Speiseanschluss zu leiten, und jede der zweiten Schalteinrichtungen, die mit einem negativen Speiseanschluss verbunden sind, eine Diode (D2, D4, D6) enthält, die quer über der zweiten Schalteinrichtung verbunden ist, um von dem negativen Speiseanschiuss weg zu leiten.

11. Stator wie in Anspruch 10 beansprucht, bei dem ein Reibungskondensator (C) quer über jeder der Schalteinrichtungen verbunden ist.

12. Stator wie in Anspruch 8, 9, 10 oder 11 beansprucht, bei dem die Einrichtungen zum Übertragen von elektrischer Energie einen Transformator (18) umfassen.

13. Stator wie in Anspruch 6 beansprucht, der weiterhin eine getrennt betätigbare Schaltelektronik für jeden leitenden Ring enthält.

14. Stator wie in Anspruch 11 beansprucht, bei dem jede der Schaltelektroniken so ist, wie in Anspruch 8, 9, 10, 11 oder 12 beansprucht.

15. Mehrphasige Reluktanzmaschine mit einem Rotor und einem Stator, wie in einem der vorhergehenden Ansprüche beansprucht.

16. Verfahren zur Ansteuerung einer geschalteten Reluktanzmaschine mit einem Stator, wie in einem der Ansprüche 8 bis 14 beansprucht, wobei das Verfahren Folgendes umfasst:

a) eine Speisespannung quer über den positiven und negativen Speiseanschlüssen anzulegen,
b) einen Phasenleitungszyklus zu starten, indem der erste Schalter, der mit einem der Knoten verbunden ist, und ein zweiter Schalter, der mit einem anderen der Knoten verbunden ist, eingeschaltet werden, so dass eine positive Spannung an die Phasenwicklung zwischen den Knoten angelegt wird und der Fluss in dem dazugehörigen Magnetkreis größer wird,
c) die ersten und zweiten Schalteinrichtungen auszuschalten, wenn der zu der Phasenwicklung zwischen den Knoten gehörende Fluss einen erforderlichen Pegel erreicht,
d) einen nachfolgenden Phasenleitungszyklus zu starten, indem die erste Schaiteinrichtung, die mit dem anderen Knoten verbunden ist, und die zweite Schalteinrichtung, die mit einem weiteren, dem anderen Knoten benachbarten Knoten verbunden ist, eingeschaltet werden, so dass eine positive Spannung quer über der benachbarten Phasenwicklung zwischen diesen Knoten angelegt wird, und
e) die ersten und zweiten Schalteinrichtungen, die mit den Knoten von aufeinander folgenden benachbarten Phasenwicklungen verbunden sind, in Übereinstimmung mit den Verfahrensschritten b) bis d) sequentiell ein- und auszuschalten, um eine zyklische Folge von Phasenleitungszyklen zu starten.

17. Verfahren wie in Anspruch 16 beansprucht, welches umfasst, den Strom in einer Phase Freilaufen zu lassen, indem die ersten oder zweiten Schalteinrichtungen während eines jeweiligen Phasenleitungszyklus wiederholt zwischen Ein- und Ausschaltzuständen Pendeln gelassen werden, um die an die Phasenwicklung angelegte mittlere Spannung in dem Zyklus zu vermindern.

18. Verfahren wie in Anspruch 17 beansprucht, welches umfasst, zwischen Pendeln lassen der ersten und zweiten Schalteinrichtungen zu wechseln, um Freilauf zu bewirken.

19. Verfahren wie in Anspruch 16, 17 oder 18 beansprucht, bei dem die Gleichstrom-Speisespannung als eine Funktion der Drehzahl des Motors verändert wird.

Revendications

1. Stator pour une machine à réluctance à p-phases (p > 3), comprenant un corps de stator, un enroulement de phase (RS, ST, TR,...) pour chaque phase de la machine, et au moins un dispositif de courant unidirectionnel (DR, DS, DT,...) connecté en série à chaque enroulement de phase de manière à former une unité de phase avec celui-ci, les unités à p-phases définissant des noeuds (R, S, T) de connexion entre les unités de phase, **caractérisé en ce que** les unités de phase sont arrangées en une pluralité d'anneaux conducteurs séparés.

2. Stator suivant la revendication 1, dans lequel le au moins un dispositif de courant unidirectionnel est une diode (DR, DS, DT,...).

3. Stator suivant la revendication 2, dans lequel deux ou plus de deux diodes sont connectées en série ou en parallèle.

4. Stator suivant la revendication 1, 2 ou 3, dans lequel chaque dispositif de courant unidirectionnel est connecté à un premier côté de son enroulement de phase respectif et en ce qu'un autre dispositif de courant unidirectionnel est connecté à l'autre côté de son enroulement de phase respectif.

5. Stator suivant la revendication 4, dans lequel des paires de dispositifs de courant unidirectionnel connectés en commun à l'un des noeuds sont formées en un seul ensemble de dispositif.

6. Stator suivant la revendication 1, 2, 3, 4 ou 5, dans lequel m anneaux conducteurs comprennent jusqu'à n/2 unités (n étant pair) ou (n+1)/2 unités (n étant impair).

7. Stator suivant la revendication 6, dans lequel au moins deux anneaux conducteurs comprennent le même nombre d'unités de phase et en ce que les noeuds de chacun d'eux sont respectivement connectés ensemble.

8. Stator suivant l'une quelconque des revendications 1 à 7, comprenant en outre un circuit de commutation ayant des bornes d'alimentation de courant continu positive et négative, des premiers et deuxièmes moyens de commutation (S1-6) connectés en série pour chaque noeud, et des moyens (10, 12, 14) pour transmettre une énergie électrique entre chaque noeud de l'anneau conducteur et les premiers et deuxièmes moyens de commutation du circuit de commutation, les paires de moyens de commutation connectés en série étant connectées entre les

bornes d'alimentation positive et négative.

9. Stator suivant la revendication 8, dans lequel les moyens de transmission d'une énergie électrique comprennent une ligne électriquement conductrice (10, 12, 14) connectée entre chacun des premiers et deuxièmes moyens de commutation et le noeud correspondant, de telle sorte que le circuit de commutation soit connecté par l'une desdites lignes au noeud correspondant.

10. Stator suivant la revendication 8 ou 9, dans lequel chacun des premiers moyens de commutation connectés à la borne d'alimentation positive comprend une diode (D1, D3, D5) connectée aux bornes desdits premiers moyens de commutation pour conduire à la borne d'alimentation positive, et chacun des deuxièmes moyens de commutation connectés à la borne d'alimentation négative comprend une diode (D2, D4, D6) connectée aux bornes desdits deuxièmes moyens de commutation pour conduire depuis la borne d'alimentation négative.

11. Stator suivant la revendication 10, dans lequel un condensateur d'amortissement (C) est connecté aux bornes de chacun des moyens de commutation.

12. Stator suivant la revendication 8, 9, 10 ou 11, dans lequel les moyens de transmission d'une énergie électrique comprennent un transformateur (18).

13. Stator suivant la revendication 6, comprenant en outre un circuit de commutation actionnable séparément pour chaque anneau conducteur.

14. Stator suivant la revendication 11, dans lequel chacun des circuits de commutation est tel que revendiqué dans les revendications 8, 9, 10, 11 ou 12.

15. Machine à réluctance polyphasée, comprenant un rotor et un stator suivant l'une quelconque des revendications précédentes.

16. Procédé de commande d'une machine à réluctance commutée comprenant un stator suivant l'une quelconque des revendications 8 à 14, le procédé comprenant:

a) l'application d'une tension d'alimentation entre les bornes d'alimentation positive et négative;
b) le lancement d'un cycle de conduction de phase en activant le premier commutateur connecté à un premier des noeuds et un deuxième commutateur connecté à un autre des noeuds, de telle sorte qu'une tension positive soit appliquée à, et que le flux augmente à l'intérieur du circuit magnétique associé à l'enroulement de phase entre les noeuds;
c) la désactivation desdits premiers et deuxièmes moyens de commutation lorsque le flux associé à l'enroulement de phase entre les noeuds atteint un niveau requis;
d) le lancement d'un cycle de conduction de phase subséquent en activant les premiers moyens de commutation connectés audit autre noeud et les deuxièmes moyens de commutation connectés à un autre des noeuds à proximité dudit autre noeud, de telle sorte qu'une tension positive soit appliquée aux bornes de l'enroulement de phase voisin entre ces noeuds; et
e) l'activation et la désactivation séquentielles des premiers et deuxièmes moyens de commutation connectés aux noeuds des unités de phase adjacentes successives suivant les étapes b) à d) afin de lancer une séquence cyclique de cycles de conduction de phase.

17. Procédé suivant la revendication 16, comprenant la libre circulation du courant dans une unité de phase par l'oscillation répétée des premiers ou des deuxièmes moyens de commutation entre des états activés et désactivés durant un cycle de conduction de phase respectif afin de réduire la tension moyenne appliquée à l'enroulement de phase durant le cycle.

18. Procédé suivant la revendication 17, comprenant une alternance entre l'oscillation des premiers et des deuxièmes moyens de commutation afin d'assurer une libre circulation.

19. Procédé suivant la revendication 16, 17 ou 18, dans lequel la tension d'alimentation de courant continu est modifiée en fonction de la vitesse du moteur.

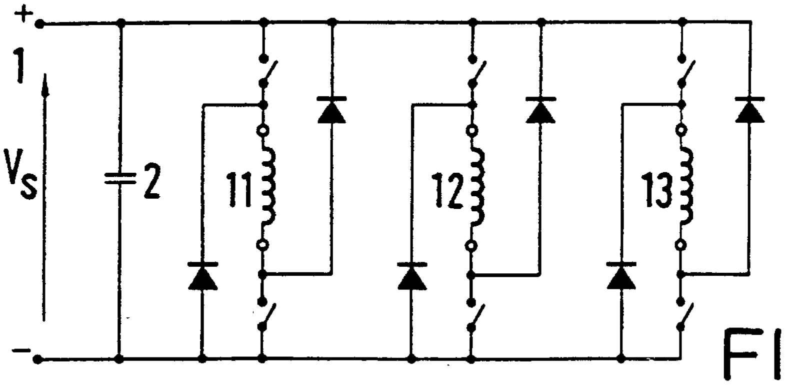


FIG.1.

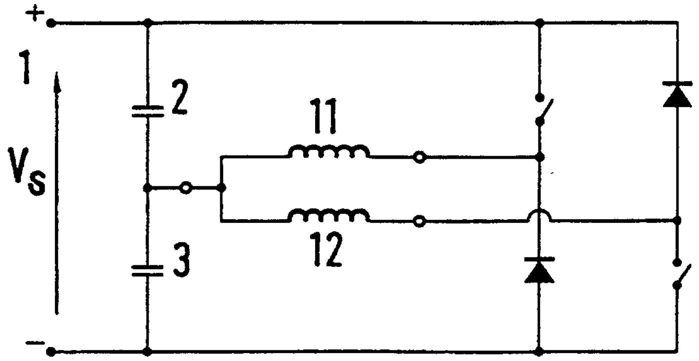


FIG.2.

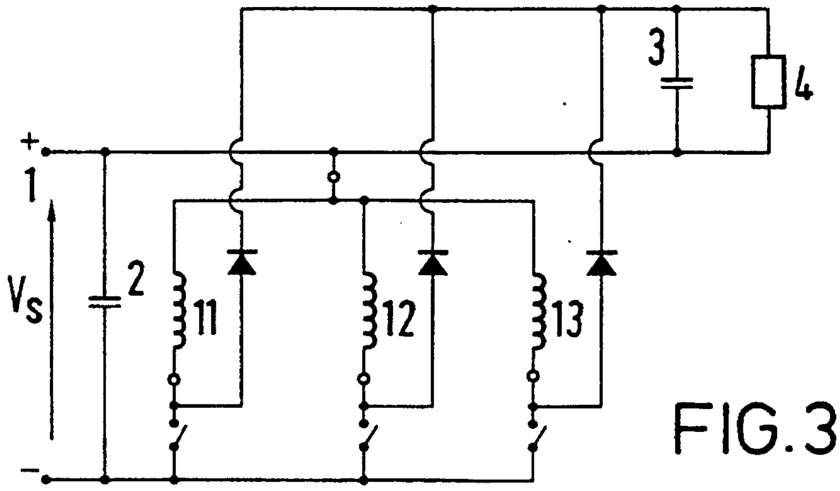


FIG.3.

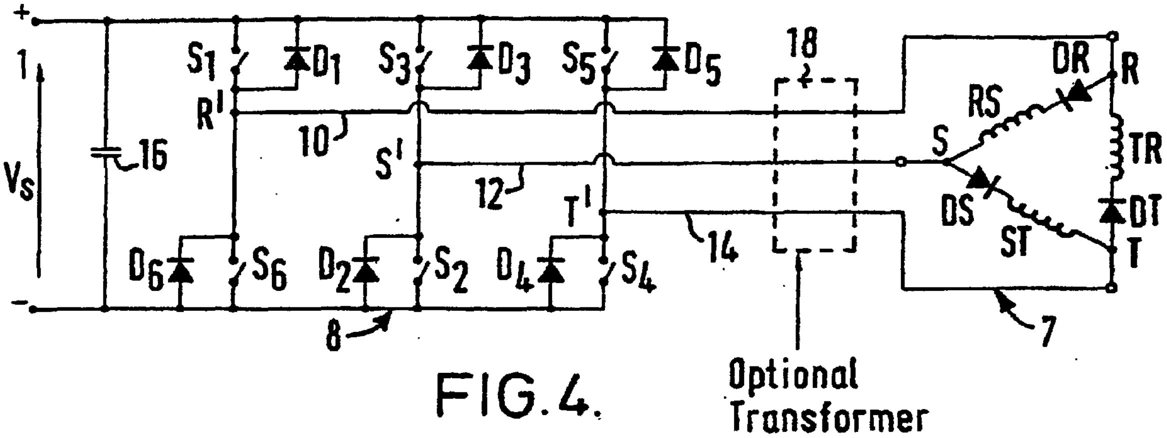


FIG.4.

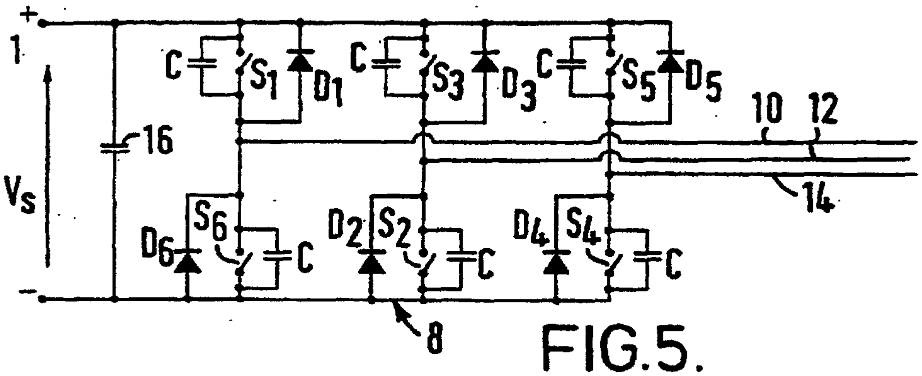


FIG.5.

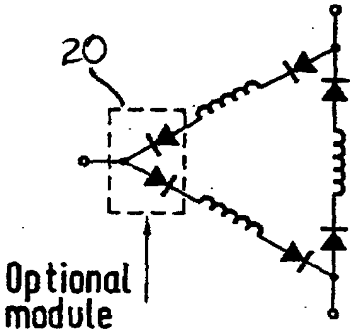


FIG.6.